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Harkness

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(54) **SELF-CLEANING PRIME MOVER EXHAUST SYSTEM AND METHOD**

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F01N 13/08 (2010.01)
F01N 3/00 (2006.01)

(52) **U.S. Cl.**
CPC ***F01N 13/082*** (2013.01); ***F01N 3/005*** (2013.01); ***F01N 3/02*** (2013.01); *F01N 2260/06* (2013.01); *F01N 2470/30* (2013.01); *F01N 2590/08* (2013.01)

(58) **Field of Classification Search**
CPC F01N 3/005; F01N 2470/30
See application file for complete search history.

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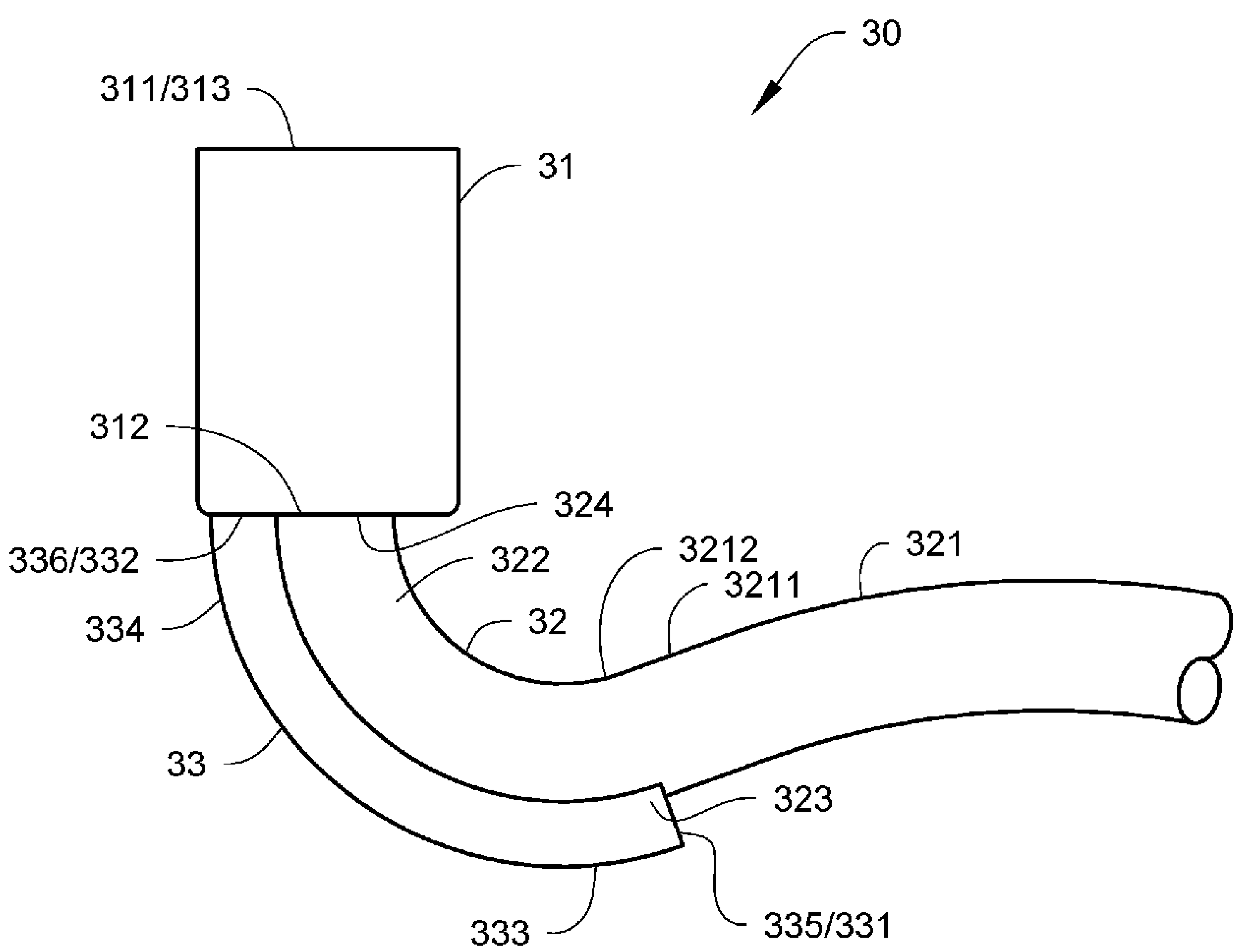
(57) **ABSTRACT**

This disclosure relates generally to a prime mover system. More specifically, this disclosure relates to a prime mover exhaust system that can prevent the accumulation of debris (e.g., soot or unburned fuel) in the prime mover system. In accordance with at least one embodiment described and recited herein, a self-cleaning prime mover exhaust system is provided. The prime mover exhaust system includes an exhaust tip, an exhaust pipe, and a cleaning tube. The exhaust tip is configured to eject exhaust out of the prime mover exhaust system, the exhaust pipe is configured to direct the exhaust away from a prime mover, and the cleaning tube is configured to accumulate debris exiting from the exhaust pipe and configured to vacuum the debris out of the self-cleaning prime mover exhaust system through the exhaust tip using the Venturi effect.

20 Claims, 9 Drawing Sheets



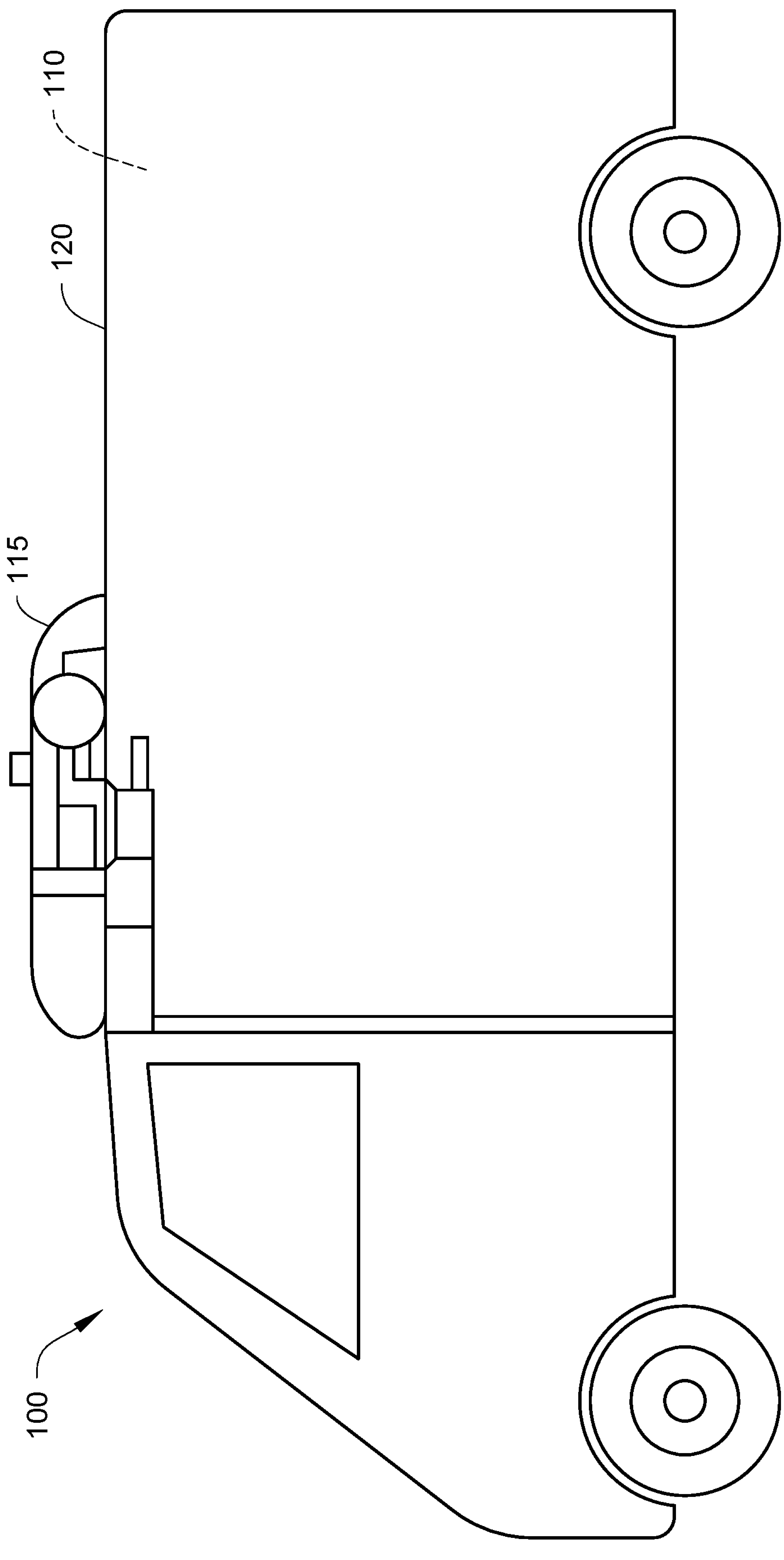


Fig. 1A

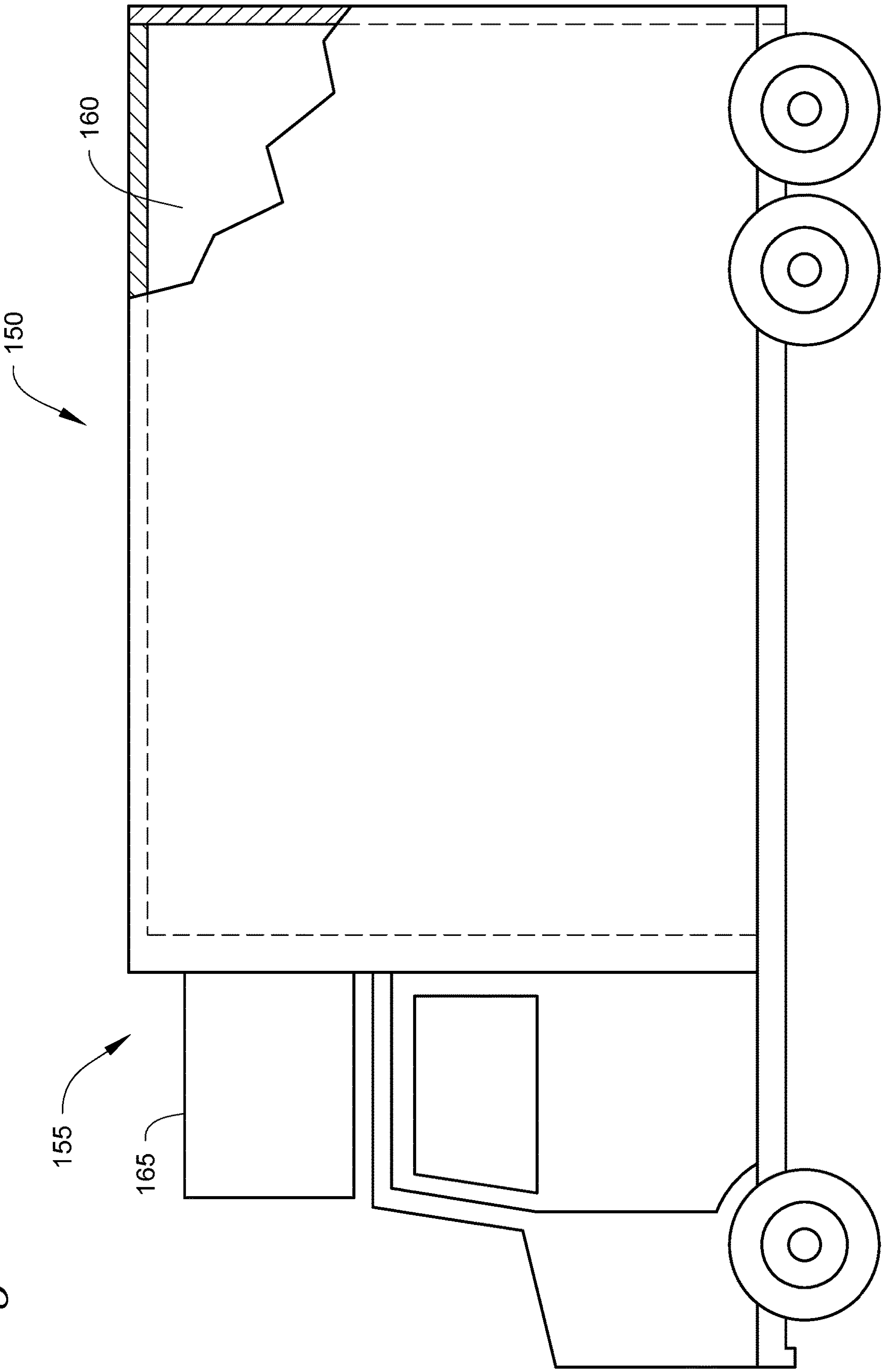


Fig. 1B

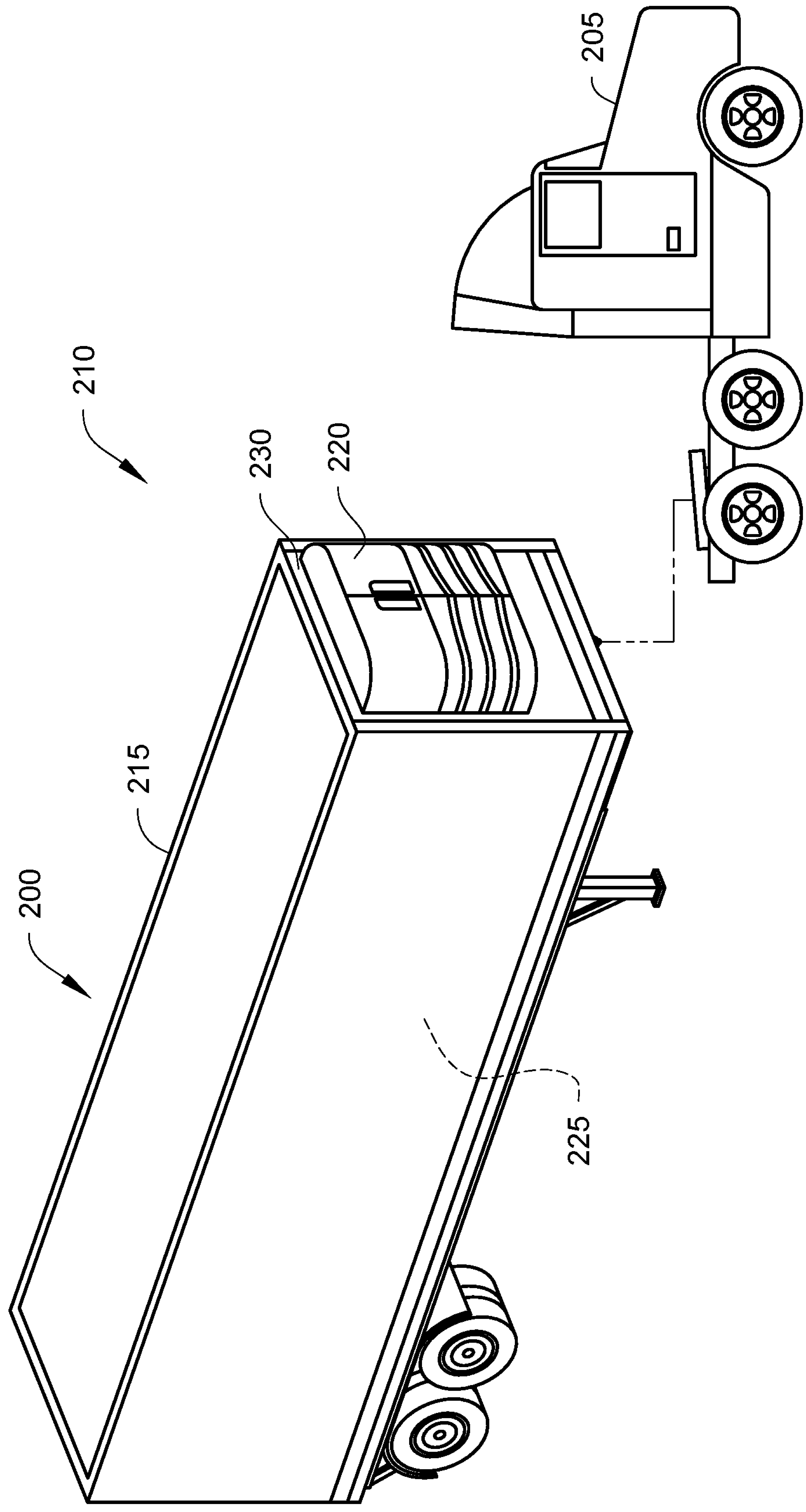
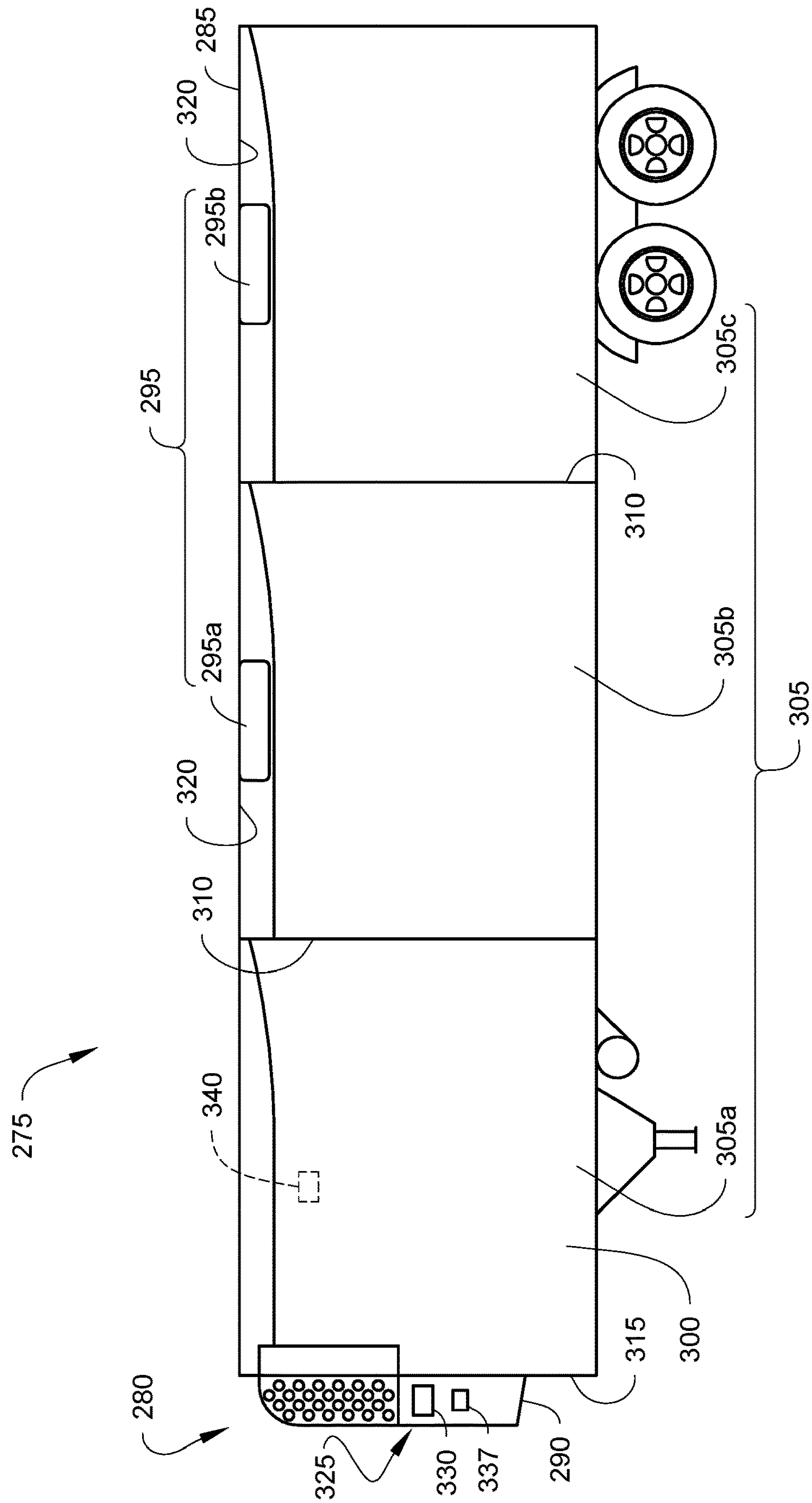


Fig. 1C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280
285
290
295
295a
295b
300
305
305a
305b
305c
310
310
315
320
320
325
330
337
340

Fig. 1D

Fig. 2

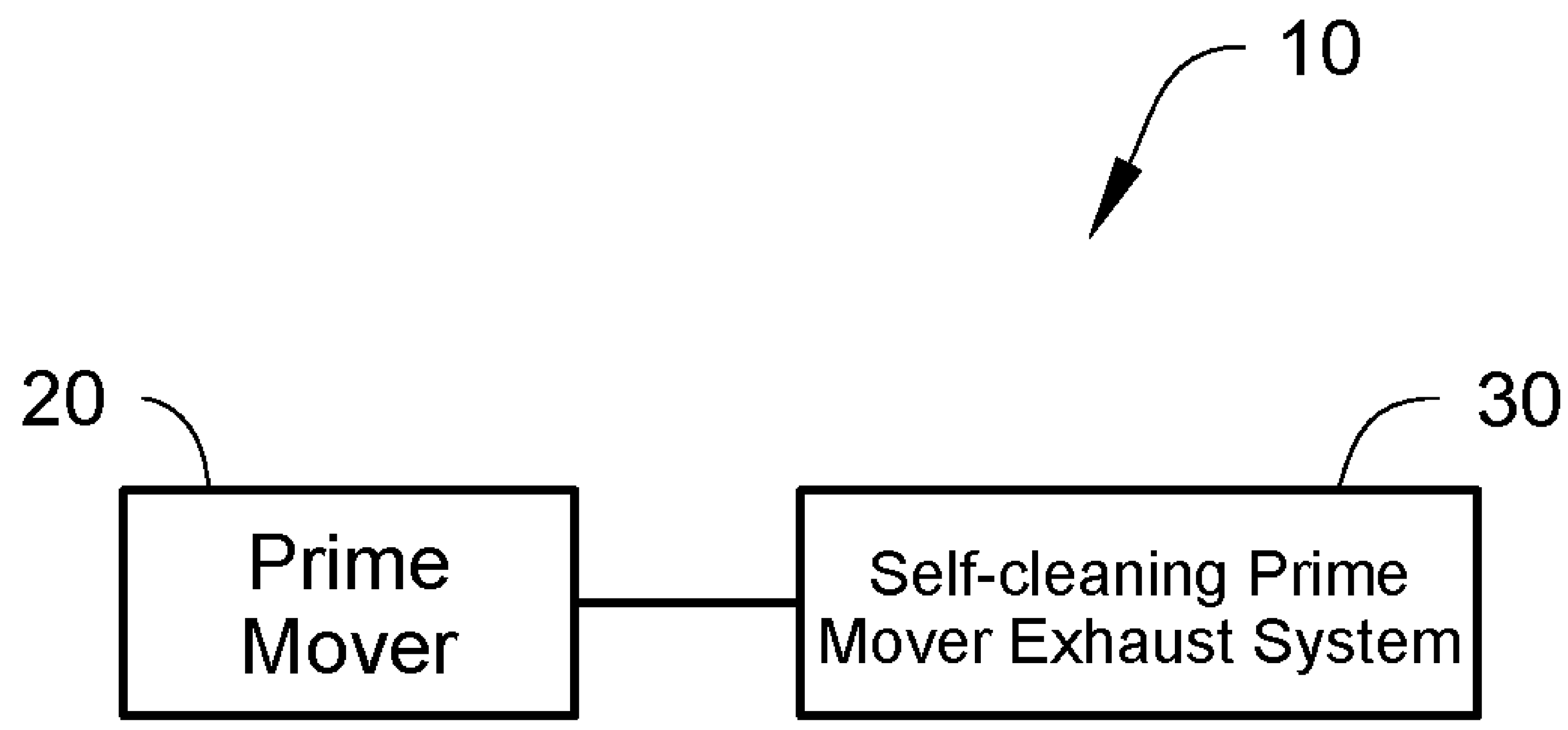

10
20
30
Prime Mover
Self-cleaning Prime Mover Exhaust System

Fig. 3

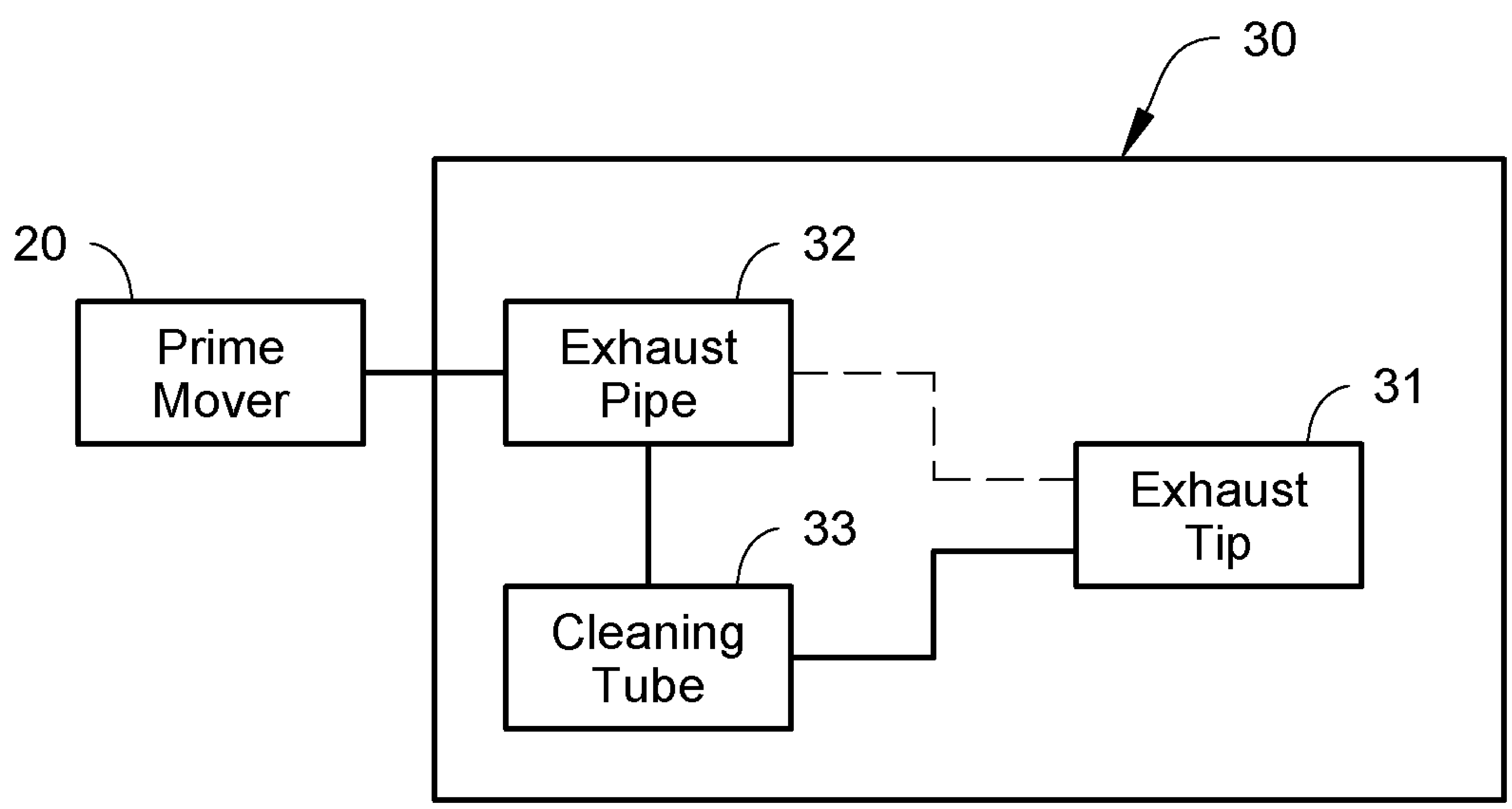

30
20
32
31
33
Prime Mover
Exhaust Pipe
Exhaust Tip
Cleaning Tube

Fig. 4

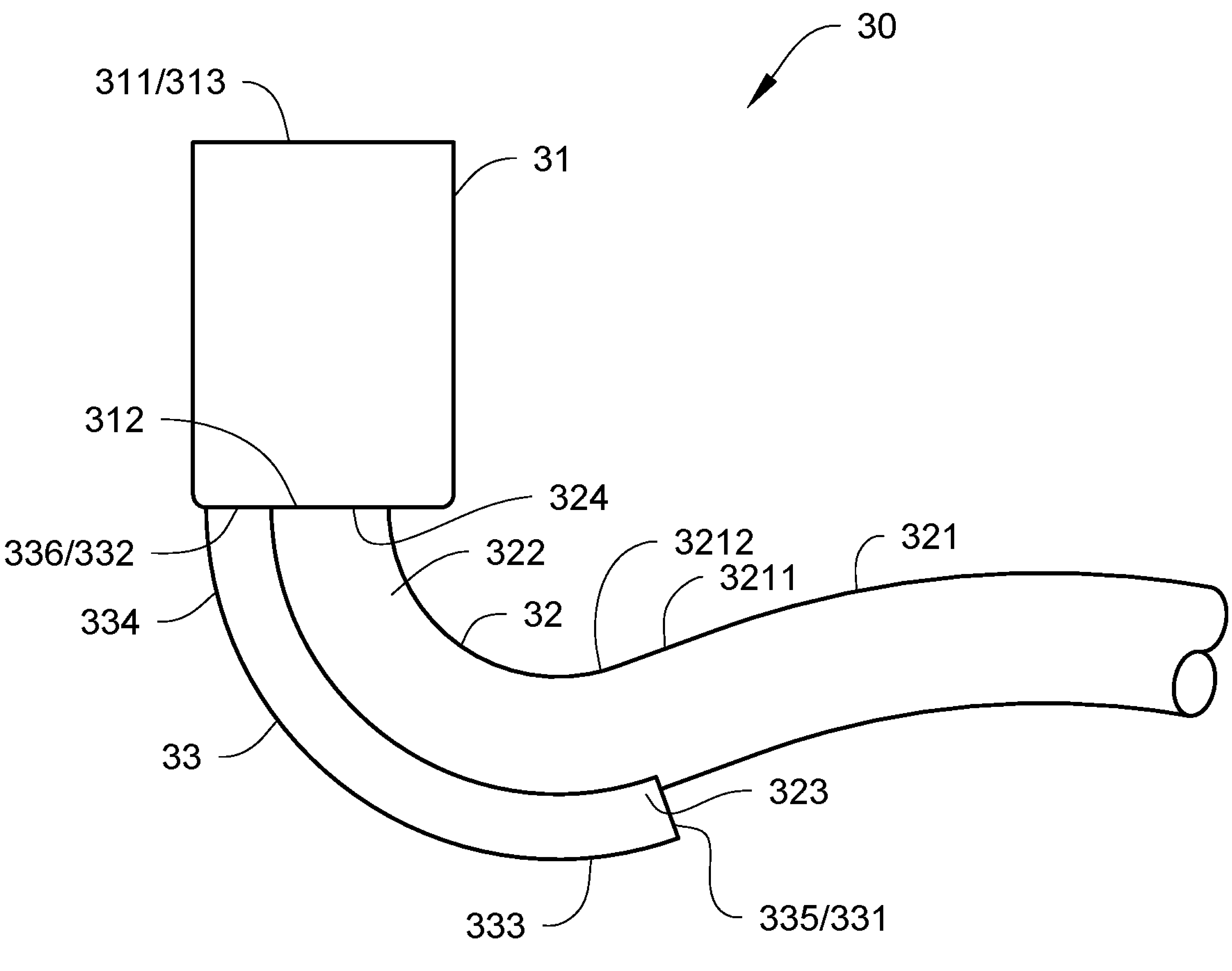

30
311/313
31
312
324
336/332
322
3212
321
3211
334
32
33
323
333
335/331

Fig. 5

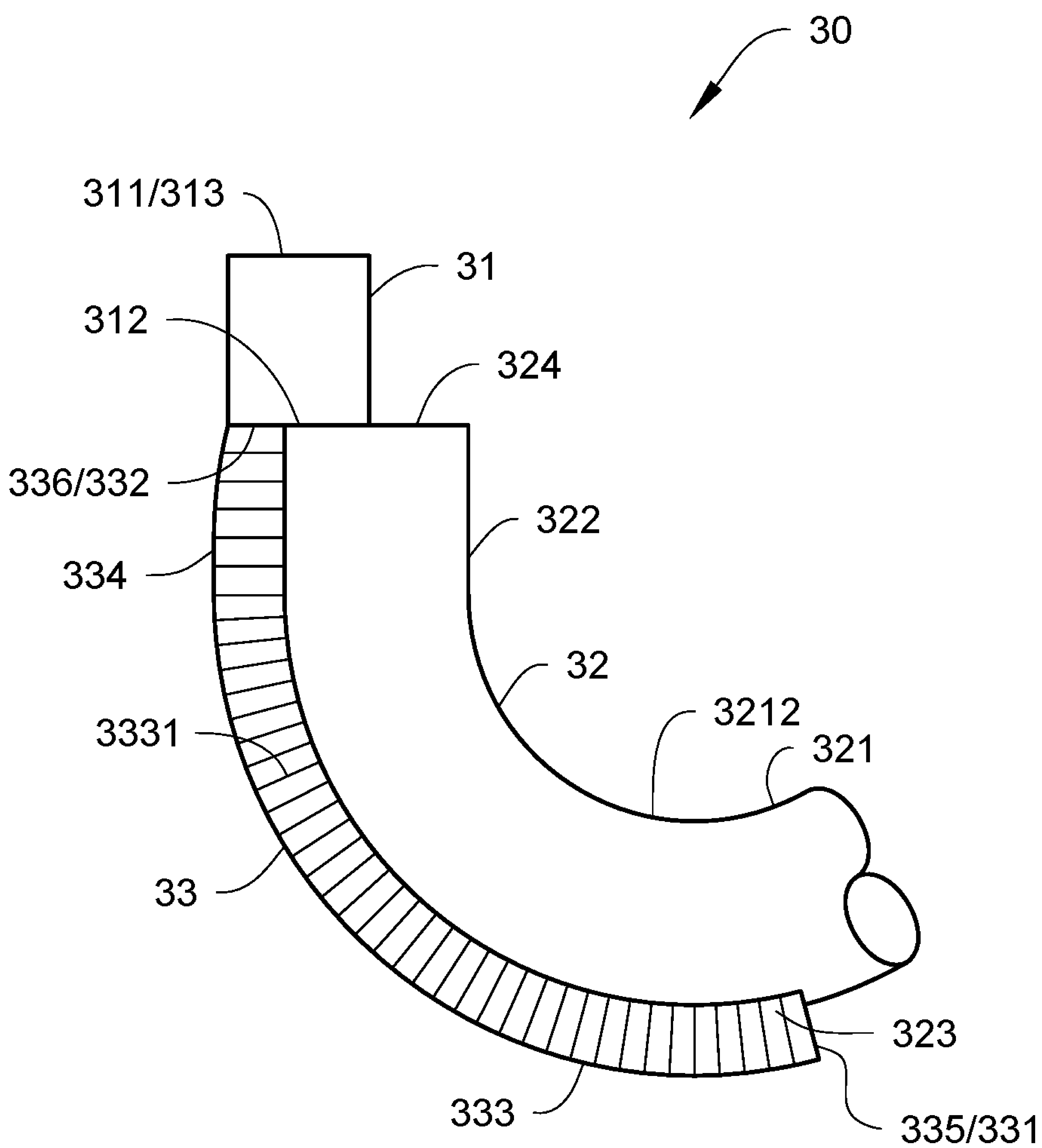

30
311/313
31
312
324
336/332
322
334
32
3212
321
3331
33
323
333
335/331

Fig. 6

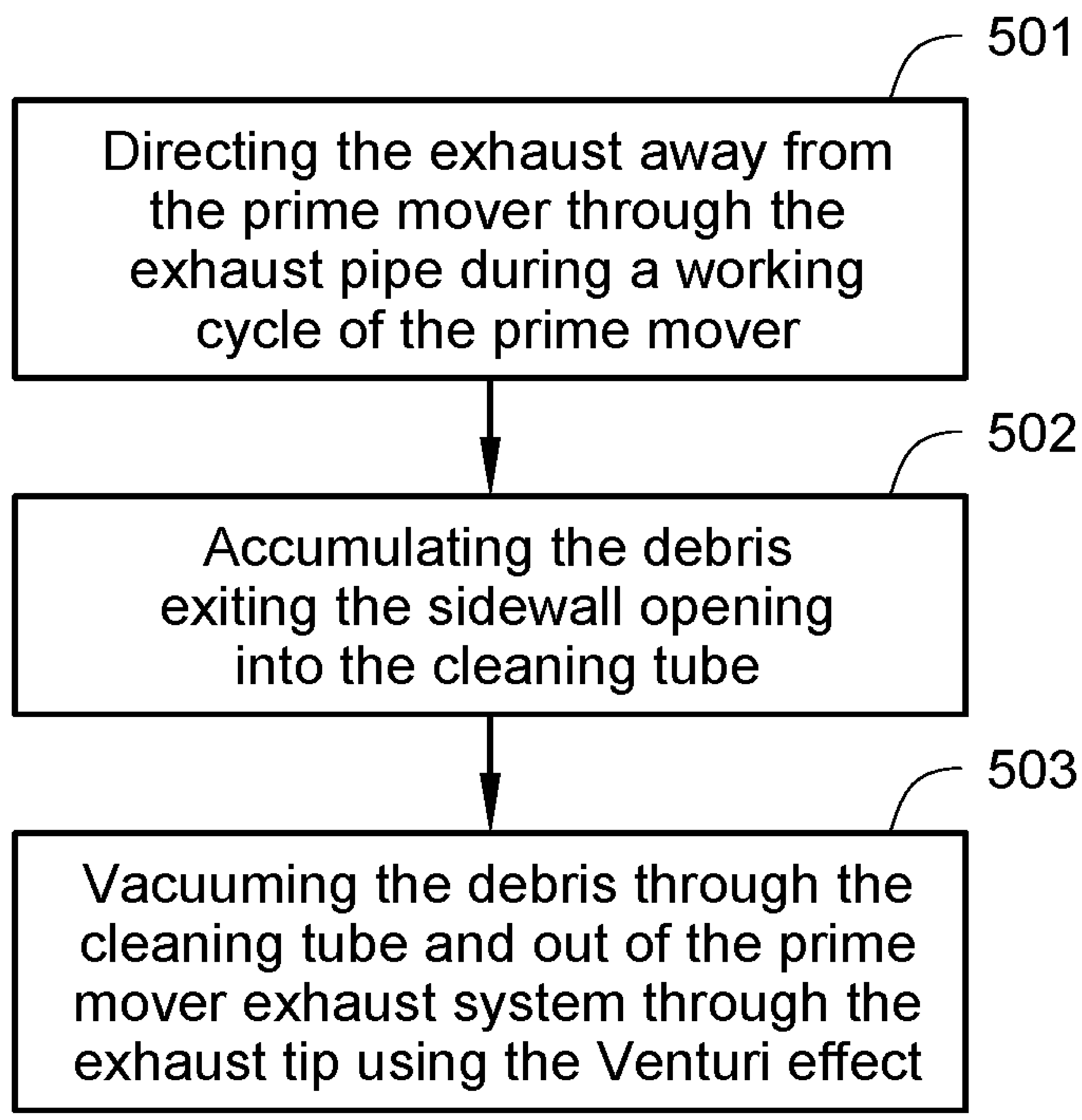
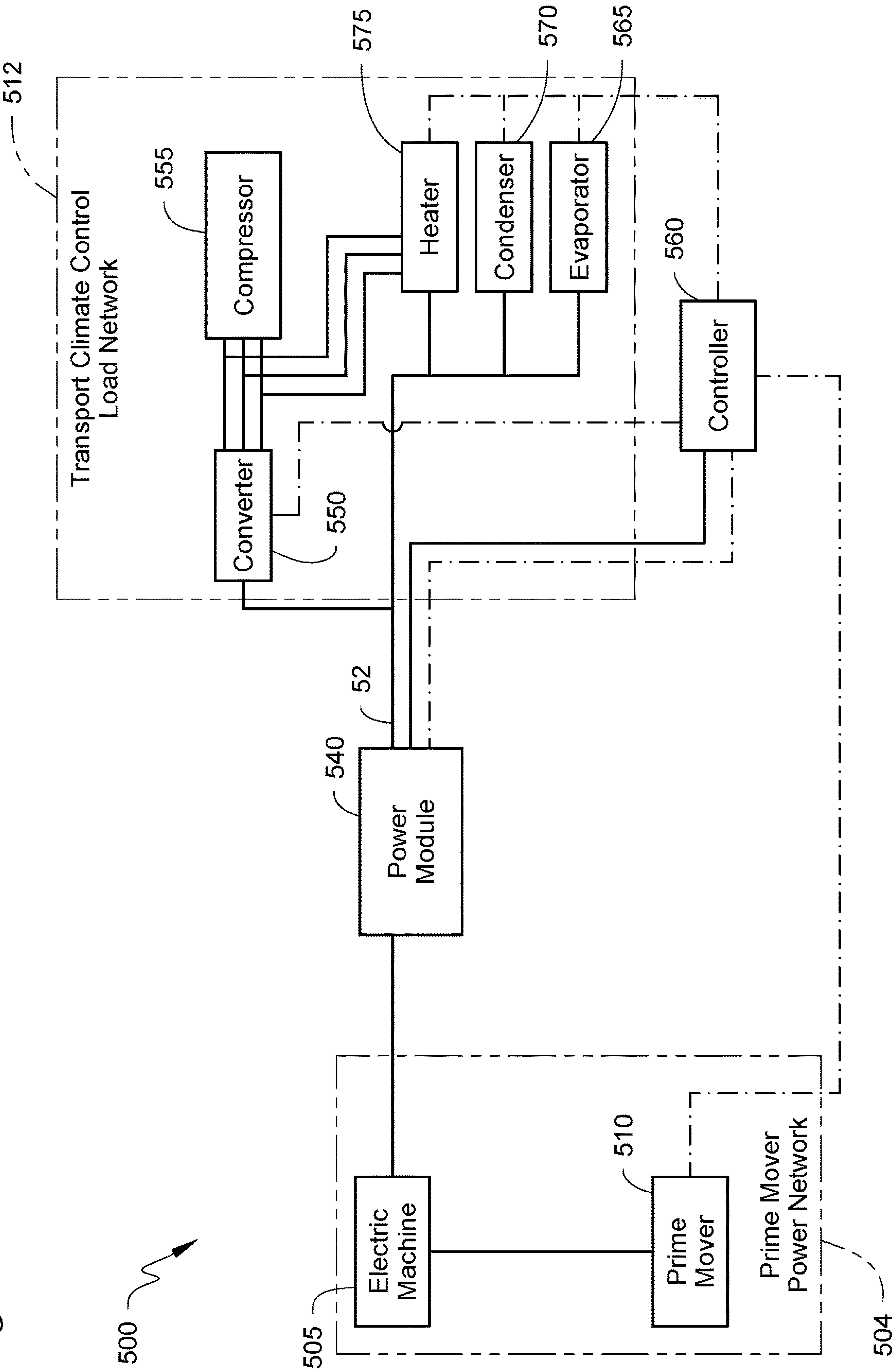

501
Directing the exhaust away from the prime mover through the exhaust pipe during a working cycle of the prime mover
502
Accumulating the debris exiting the sidewall opening into the cleaning tube
503
Vacuuming the debris through the cleaning tube and out of the prime mover exhaust system through the exhaust tip using the Venturi effect

Fig. 7


500
512
Transport Climate Control Load Network
555
Compressor
575
Heater
570
Condenser
565
Evaporator
560
Controller
Converter
550
52
540
Power Module
505
Electric Machine
510
Prime Mover
Prime Mover Power Network
504

SELF-CLEANING PRIME MOVER EXHAUST SYSTEM AND METHOD

FIELD

This disclosure relates generally to a prime mover system. More specifically, this disclosure relates to a self-cleaning prime mover exhaust system that can self-clean to remove the accumulation of debris (e.g., soot or unburned fuel) in the prime mover system.

BACKGROUND

A prime mover system is generally a mechanical system using a prime mover to convert one or more forms of energy into mechanical force, and making use of the mechanical force to realize some kind of specific function, like climate control, wheel driving, or concrete mixing. Examples of the prime mover include, but are not limited to an engine or motor used in a transport unit. Examples of transport units include, but are not limited to a truck, a container (such as a container on a flat car, an intermodal container, a marine container, a rail container, etc.), a box car, a semi-tractor, a bus, or other similar transport units.

Exhaust waste may be generated during the energy-converting process of the prime mover. Thus, one or more prime mover exhaust systems may be provided in a prime mover system to discharge the exhaust waste.

SUMMARY

This disclosure relates generally to a prime mover system. More specifically, this disclosure relates to a self-cleaning prime mover exhaust system that can self-clean to remove the accumulation of debris (e.g., soot or unburned fuel) in the prime mover system.

In accordance with at least one embodiment described and recited herein, a self-cleaning prime mover exhaust system is provided. The self-cleaning prime mover exhaust system includes an exhaust tip, an exhaust pipe, and a cleaning tube. The exhaust tip is configured to eject exhaust out of the self-cleaning prime mover exhaust system, the exhaust pipe is configured to direct the exhaust away from a prime mover, and the cleaning tube is configured to accumulate debris exiting from the exhaust pipe and configured to vacuum the debris out of the self-cleaning prime mover exhaust system through the exhaust tip using the Venturi effect.

Specifically, the exhaust pipe includes a first exhaust section and a second exhaust section. The first exhaust section includes a side wall opening, and the second exhaust section includes an exhaust opening configured to direct the exhaust out of the exhaust pipe.

The cleaning tube includes a first end and a second end, and the cleaning tube has a smaller sectional area compared with the exhaust tip. The cleaning tube further includes a first cleaning section and a second cleaning section. The first cleaning section covers the sidewall opening to make sure the debris exiting from the sidewall opening can be accumulated in the cleaning tube. The first cleaning section includes a first cleaning opening at the first end of the cleaning tube. The second cleaning section extends through the exhaust tip and includes a second cleaning opening at the second end of the cleaning tube.

In accordance with at least one other embodiment described and recited herein, a prime mover system is provided. The prime mover system includes a prime mover configured to generate mechanical power, and a self-cleaning prime mover exhaust system mentioned above configured to self-clean to remove the debris accumulated.

In accordance with at least one other embodiment described and recited herein, a method for self-cleaning debris from a self-cleaning prime mover exhaust system mentioned above is provided. The method includes directing exhaust away from the prime mover through the exhaust pipe during a working cycle of the prime mover; accumulating debris exiting the sidewall opening into the cleaning tube; and vacuuming debris through the cleaning tube and out of the self-cleaning prime mover exhaust system through the exhaust tip.

In accordance with the embodiments described and recited herein, debris may flow back in the exhaust pipe since there would be no exhaust flow in the exhaust pipe between the working cycles of the prime mover, and the debris would exit from the sidewall opening of the exhaust pipe and would be accumulated in the first cleaning section of the cleaning tube. Since the cleaning tube has a smaller sectional area compared with the exhaust tip, vacuuming air flow can be formed in the cleaning tube because of the Venturi effect, and the accumulated debris will be vacuumed through the cleaning tube and discharged out of the self-cleaning prime mover exhaust system through the exhaust tip. Thus, the safety risk that would be caused by the accumulated debris can be effectively reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

In the detailed description that follows, embodiments are described as illustrations only since various changes and modifications will become apparent to those skilled in the art from the following detailed description. The use of the same reference numbers in different figures indicates similar or identical items.

FIG. **1**A is a side view of a van with a transport climate control system, in accordance with one or more embodiments described and recited herein.

FIG. **1**B is a side view of a truck with a transport climate control system, in accordance with one or more embodiments described and recited herein.

FIG. **1**C is a perspective view of a climate controlled transport unit attachable to a tractor, in accordance with one or more embodiments described and recited herein.

FIG. **1**D is a side view of a climate controlled transport unit including a multi-zone transport climate control system, in accordance with one or more embodiments described and recited herein.

FIG. **2** shows a block diagram of a prime mover system, according to at least one embodiment described and recited herein.

FIG. **3** shows a block diagram of a self-cleaning prime mover exhaust system, according to at least one embodiment described and recited herein.

FIG. **4** shows a schematic diagram of a self-cleaning prime mover exhaust system, according to at least one embodiment described and recited herein.

FIG. **5** shows a schematic diagram of another self-cleaning prime mover exhaust system, according to at least one embodiment described and recited herein.

FIG. **6** shows a flow chart illustrating a method of self-cleaning debris from a self-cleaning prime mover exhaust system, according to at least one embodiment described and recited herein.

FIG. **7** shows a block diagram schematic of a power system for powering a transport climate control system, according to at least one embodiment described and recited herein.

DETAILED DESCRIPTION

This disclosure relates generally to a prime mover system. More specifically, this disclosure relates to a self-cleaning prime mover exhaust system that can self-clean to remove the accumulation of debris (e.g., soot or unburned fuel) in the prime mover system.

In the following detailed description, reference is made to the accompanying drawings, which form a part of the description. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. Furthermore, unless otherwise noted, the description of each successive drawing may reference features from one or more of the previous drawings to provide clearer context and a more substantive explanation of the current example embodiment. Still, the example embodiments described in the detailed description, drawings, and claims are not intended to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein and illustrated in the drawings, may be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

In the present description and recitation, the following terms may be used, in addition to their accepted meaning, as follows:

A prime mover system is a mechanical system using a prime mover to convert one or more forms of energy into mechanical force, and making use of the mechanical force to realize some kind of specific function, like climate control, wheel driving, or concrete mixing. Examples of the prime mover include, but are not limited to, an engine or motor used in a transport unit. Examples of transport units include, but are not limited to a truck, a container (such as a container on a flat car, an intermodal container, a marine container, a rail container, etc.), a box car, a semi-tractor, a bus, or other similar transport units. A refrigerated transport unit is commonly used to transport perishable items such as pharmaceuticals, produce, frozen foods, and meat products.

A self-cleaning prime mover exhaust system is generally a system configured to discharge the exhaust waste generated during the energy-converting process of the prime mover. In at least one embodiment of the present application, the self-cleaning prime mover exhaust system is further configured to self-clean to remove the accumulation of debris formed by the energy-converting process, like soot or unburned fuel formed by an incomplete fuel burning process. The accumulation of the debris may have a safety risk to be ignited by the burning sparks expelled by the prime mover. Furthermore, cosmetic benefits would also be achieved by preventing the accumulation of exhaust deposits on equipment such as an exterior of a transport climate control unit, an exterior of exterior transport container, or other exterior surfaces.

The Venturi effect is a physical phenomenon of the reduction in fluid pressure that results when a fluid flows through a constricted section of a pipe. When a fluid is flowing through a pipe including a first section with a comparatively larger section area and a second section with a comparatively smaller section area, the fluid pressure in the second section will be lower than the fluid pressure in the first section.

A transport climate control system may control one or more environmental conditions within a transport unit that include but are not limited to temperature, humidity, air quality, or combinations thereof.

A climate-controlled transport unit, e.g., a transport unit including a climate control system, may be used to transport perishable items including, but not limited to, produce, frozen foods, meat products, dairy products, etc.

A climate control system is generally used to control one or more environmental conditions such as, but not limited to, temperature, humidity, and/or air quality of a transport unit. A climate control system may include, for example, one or more of a refrigeration system to control the refrigeration of a climate-controlled space of a refrigerated transport unit; a vapor-compressor type refrigeration system, a thermal accumulator type system, or any other suitable refrigeration system that may use refrigerant, cold plate technology, etc.

A climate control system may further include a climate control unit (CCU) attached to a transport unit to control one or more environmental conditions (e.g., temperature, humidity, air quality, etc.) of a climate-controlled space of the refrigerated transport unit. The CCU may include, without limitation, one or more of a compressor, a condenser, an expansion valve, an evaporator, and one or more fans or blowers to control the heat exchange between the air within the climate-controlled space and the ambient air outside of the refrigerated transport unit.

FIGS. **1A-1**D show various transport climate control systems. FIG. **1**A is a side view of a van **100** with a transport climate control system **105**, in accordance with one or more embodiments described and recited herein. FIG. **1**B is a side view of a truck **150** with a transport climate control system **155**, in accordance with one or more embodiments described and recited herein. FIG. **1**C is a perspective view of a climate controlled transport unit **200** attachable to a tractor **205**, in accordance with one or more embodiments described and recited herein. FIG. **1**D is a side view of a climate controlled transport unit **275** including a multi-zone transport climate control system **280**, in accordance with one or more embodiments described and recited herein. It will be appreciated that the embodiments described are not limited to the transport units shown in FIGS. **1A-1**D, but may apply to any type of transport unit (e.g., a truck, a container (such as a container on a flat car, an intermodal container, a marine container, a rail container, etc.), a box car, a semi-tractor, a bus, or other similar transport unit), within the scope of the principles of this disclosure.

FIG. **1**A depicts the van **100** having the climate control system **105** for providing climate control within a climate controlled space **110**. The transport climate control system **105** includes a climate control unit (CCU) **115** that is mounted to a rooftop **120** of the van **100**. In accordance with one or more embodiments described and recited herein, the CCU **115** may be a transport refrigeration unit.

The CCU **115** may include, among other components, a climate control circuit that connects, for example, a compressor, a condenser, an evaporator, and an expansion device (e.g., an expansion valve) to provide climate control within the climate controlled space **110**.

FIG. **1**B depicts the climate-controlled straight truck **150** that includes the climate controlled space **160** for carrying cargo and the transport climate control system **155**. The transport climate control system **155** includes a CCU **165** that is mounted to a front wall **170** of the climate controlled space **160**. The CCU **165** may include, among other components, a climate control circuit that connects, for example, a compressor, a condenser, an evaporator, and an expansion device to provide climate control within the climate controlled space **160**. In accordance with one or more embodiments described and recited herein, the CCU **165** may be a transport refrigeration unit.

FIG. **1**C illustrates one embodiment of the climate controlled transport unit **200** attached to a tractor **205**. The climate controlled transport unit **200** includes a transport climate control system **210** for a transport unit **215**. The tractor **205** is attached to and may be configured to tow the transport unit **215**. The transport unit **215** shown in FIG. **1**C is a trailer.

The transport climate control system **210** may include, among other components, a CCU **220** that provides environmental control (e.g. temperature, humidity, air quality, etc.) within a climate controlled space **225** of the transport unit **215**. The CCU **220** is disposed on a front wall **230** of the transport unit **215**. In at least one or more other embodiments, the CCU **220** may be disposed, for example, on a rooftop or another wall of the transport unit **215**. The CCU **220** includes a climate control circuit that connects, for example, a compressor, a condenser, an evaporator, and an expansion device to provide conditioned air within the climate controlled space **225**. In accordance with one or more embodiments described and recited herein, the CCU **220** may be a transport refrigeration unit.

FIG. **1**D illustrates an embodiment of the climate controlled transport unit **275**. The climate controlled transport unit **275** includes the multi-zone transport climate control system (MTCS) **280** for a transport unit **285** that may be towed, for example, by a tractor (not shown). It will be appreciated that the embodiments described herein are not limited to tractor and trailer units, but may apply to any type of transport unit (e.g., a truck, a container (such as a container on a flat car, an intermodal container, a marine container, a rail container, etc.), a box car, a semi-tractor, a bus, or other similar transport unit), etc.

The MTCS **280** includes a CCU **290** and a plurality of remote units **295** that provide environmental control (e.g. temperature, humidity, air quality, etc.) within a climate controlled space **300** of the transport unit **275**. The climate controlled space **300** may be divided into a plurality of zones **305**. The term "zone" means a part of an area of the climate controlled space **300** separated by walls **310**. The CCU **290** may operate as a host unit and provide climate control within a first zone **305***a* of the climate controlled space **300**. The remote unit **295***a* may provide climate control within a second zone **305***b* of the climate controlled space **300**. The remote unit **295***b* may provide climate control within a third zone **305***c* of the climate controlled space **300**. Accordingly, the MTCS **280** may be used to separately and independently control environmental condition(s) within each of the multiple zones **305** of the climate controlled space **300**.

The CCU **290** is disposed on a front wall **315** of the transport unit **275**. In one or more other embodiments, the CCU **290** may be disposed, for example, on a rooftop or another wall of the transport unit **275**. The CCU **290** includes a climate control circuit that connects, for example, a compressor, a condenser, an evaporator, and an expansion device to provide conditioned air within the climate controlled space **300**. The remote unit **295***a* is disposed on a ceiling **320** within the second zone **305***b* and the remote unit **295***b* is disposed on the ceiling **320** within the third zone **305***c*. Each of the remote units **295***a* and **295***b* includes an evaporator that connects to the rest of the climate control circuit provided in the CCU **290**. In accordance with one or more embodiments described and recited herein, the CCU **290** may be a transport refrigeration unit.

The MTCS **280** may also include a programmable climate controller **325** and one or more climate control sensors (not shown) that are configured to measure one or more parameters of the MTCS **280** (e.g., an ambient temperature outside of the transport unit **275**, an ambient humidity outside of the transport unit **275**, a compressor suction pressure, a compressor discharge pressure, supply air temperatures of air supplied by the CCU **290** and the remote units **295** into each of the zones **305**, return air temperatures of air returned from each of the zones **305** back to the respective CCU **290** or remote unit **295***a* or **295***b*, a humidity within each of the zones **305**, etc.) and communicate climate control data to a climate controller **325**. The one or more climate control sensors may be positioned at various locations outside the transport unit **275** and/or inside the transport unit **275** (including within the climate controlled space **300**).

The climate controller **325** may be configured to control operation of the MTCS **280** including components of the climate control circuit. The climate controller **325** may include a single integrated control unit **330** or may include a distributed network of climate controller elements **330**, **337**. The number of distributed control elements in a given network may depend upon the particular application of the principles described herein. The measured parameters obtained by the one or more climate control sensors may be used by the climate controller **325** to control operation of the MTCS **280**.

FIG. **2** shows a block diagram of a prime mover system, according to at least one embodiment described and recited herein. As shown in FIG. **2**, the prime mover system **10** includes a prime mover **20** configured to generate mechanical power, and a self-cleaning prime mover exhaust system **30** mentioned above configured to self-clean to remove the debris accumulated.

The prime mover **20** is configured to convert one or more forms of energy into mechanical force, and the mechanical force is used to realize some kind of specific function of the prime mover system **10**. For example, the prime mover **20** may be a diesel/gasoline motor used for driving the vehicle wheels of a truck or trailer, or driving a compressor, a condenser, an evaporator, or an expansion device (e.g., an expansion valve) to provide climate control. The specific models of the prime mover **20** may vary with the specific functions to be realized by the prime mover system **10** and are not limited to the above examples.

The self-cleaning prime mover exhaust system **30** is generally configured to discharge the exhaust formed by the energy-converting process. However, when the prime mover **20** is working to provide mechanical power, debris may be also created together with the exhaust during the energy-converting process. For example, soot and unburned fuel may be created when the prime mover **20** is implementing a cold start under a low load status. During a cold start process, the prime mover **20** may execute multiple working cycles to make sure a successful ignition. In each working cycle, the debris may flow with the exhaust and be discharged by the self-cleaning prime mover exhaust system **30**. But between the working cycles, since the prime mover **20** is not implementing the energy-converting process and no new exhaust is created, there would be no exhaust flow in the self-cleaning prime mover exhaust system **30**. The exhaust would not be pushed out of the exhaust system, and the debris would flow back with the exhaust and be accumulated somewhere in the exhaust system, or exit from some opening of the exhaust system and be accumulated outside the exhaust system. In this case, when the next working cycle comes, burning embers or sparks would be expelled when the prime mover **20** starts another ignition process, and the accumulated debris would have a risk to be ignited by the burning embers or sparks, which may cause severe safety problem of the whole prime mover system **10**. Thus, in order to reduce the safety risk mentioned above, the self-cleaning prime mover exhaust system **30**, according to at least one embodiment of the present application, is further configured to self-clean to remove the accumulation of debris.

In some embodiment of the present application, the prime mover system **10** may further include an exhaust fan **40** configured to vacuum the exhaust from the self-cleaning prime mover exhaust system **30**.

FIG. **3** shows a block diagram of a self-cleaning prime mover exhaust system, according to at least one embodiment described and recited herein. As shown in FIG. **3**, the self-cleaning prime mover exhaust system **30** includes an exhaust tip **31**, an exhaust pipe **32**, and a cleaning tube **33**. The exhaust tip **31** is configured to eject exhaust out of the self-cleaning prime mover exhaust system **30**, the exhaust pipe **32** is configured to direct the exhaust away from a prime mover **20**, and the cleaning tube **33** is configured to accumulate debris exiting from the exhaust pipe **32** and vacuum the debris out of the self-cleaning prime mover exhaust system **30** through the exhaust tip **31**.

Specifically, the exhaust pipe **32** includes a first exhaust section **321** and a second exhaust section **322**. The first exhaust section **321** includes a sidewall opening **323**, and the second exhaust section **322** includes an exhaust opening **324** configured to direct the exhaust out of the exhaust pipe **32**.

The cleaning tube **33** includes a first end **331** and a second end **332**, and the cleaning tube **33** has a smaller sectional area compared with the exhaust tip **31**. The cleaning tube **33** further includes a first cleaning section **333** and a second cleaning section **334**. The first cleaning section **333** covers the sidewall opening **323** to make sure the debris exiting from the sidewall opening **323** can be accumulated in the cleaning tube **33**. The first cleaning section **333** includes a first cleaning opening **335** at the first end **331** of the cleaning tube **33**. The second cleaning section **334** extends through the exhaust tip **31** and includes a second cleaning opening **336** at the second end **332** of the cleaning tube **33**.

As discussed above, debris may flow back in the exhaust pipe **32** since there would be no exhaust flow in the exhaust pipe **32** between the working cycles of the prime mover **20**, and the debris would exit from the sidewall opening **323** of the exhaust pipe **32** and would be accumulated in the first cleaning section **333** of the cleaning tube **33**. Since the cleaning tube **33** has a smaller sectional area compared with the exhaust tip **31**, vacuuming air flow can be formed in the cleaning tube **33** because of the Venturi effect, and the accumulated debris will be vacuumed through the cleaning tube **33** and discharged out of the self-cleaning prime mover exhaust system **30** through the exhaust tip **31**. Thus, the safety risk that would be caused by the accumulated debris can be effectively reduced.

FIG. **4** shows a schematic diagram of a self-cleaning prime mover exhaust system **30**, according to at least one embodiment described and recited herein. FIG. **5** shows a schematic diagram of another self-cleaning prime mover exhaust system **30**, according to at least one embodiment described and recited herein.

As shown in FIGS. **4** and **5**, in some embodiments of the present application, the second exhaust section **322** may extend through the exhaust tip **31** to direct the exhaust into the exhaust tip **31**. In this case, the exhaust tip **31** would also be configured to discharge the exhaust out of the self-cleaning prime mover exhaust system **30**, so the exhaust tip **31** can be commonly used by the exhaust pipe **32** and the cleaning tube **33** as a discharging output, and the size of the whole self-cleaning prime mover exhaust system **30** could be smaller to save the inside space of the prime mover system **10**. Specifically, during the working cycle of the prime mover **20**, the exhaust tip **31** can discharge the exhaust and the debris coming through the exhaust pipe **32**; between the working cycle of the prime mover **20**, the exhaust tip **31** can discharge the debris coming through the cleaning tube **33**.

As shown in FIG. **4**, in some embodiments of the present application, the exhaust tip **31** may include an exhaust end **311**, and both the second exhaust section **322** and the second cleaning section **334** may extend through the exhaust end **311**. In this case, the exhaust tip **31** can be commonly used by the exhaust pipe **32** and the cleaning tube **33** as a discharging output, and the second exhaust section **322** and the second cleaning section **334** more specifically extend through one same end of the exhaust tip **31**. Thus, the size of the whole self-cleaning prime mover exhaust system **30** could be much smaller, and the manufacturing cost and difficulties of the self-cleaning prime mover exhaust system **30** would be reduced.

As shown in FIG. **4**, in some embodiments of the present application, the exhaust tip **31** may have a larger sectional area compared with the exhaust pipe **32**. In this case, the Venturi effect could also be taken advantage of during the working cycle of the prime mover **20**. Specifically, the exhaust flow would have a lower pressure in exhaust pipe **32** compared with that in exhaust tip **31**, since exhaust pipe **32** has a smaller section area compared with exhaust tip **31**. Thus, external vacuuming air flow would be formed at the sidewall opening **323** of the exhaust pipe **32**, and the external vacuuming air flow can further facilitate the discharging of the exhaust from the exhaust pipe **32** to the exhaust tip **31**.

As shown in FIG. **4**, in some embodiments of the present application, both the exhaust opening **324** and the second cleaning opening **336** may be disposed of within the exhaust end **311**. In this case, the exhaust end **311** has a larger sectional area compared with the exhaust pipe **32**, Venturi effect could also be taken advantage of to form the external vacuuming air flow facilitating the discharging of the exhaust from the exhaust pipe **32** to the exhaust tip **31**. In the meantime, the second exhaust section **322** and the second cleaning section **334** more specifically extend through one same end of the exhaust tip **31**, so that the size of the whole self-cleaning prime mover exhaust system **30** could be much smaller, and the manufacturing cost and difficulties of the self-cleaning prime mover exhaust system **30** could be reduced.

As shown in FIG. **5**, in some embodiments of the present application, the exhaust tip **31** may include an exhaust input opening **312**, both the second exhaust section **322**, and the second cleaning section **334** may extend through the exhaust input opening **312**. The exhaust input opening **312** may have a sectional area that is larger compared with the second cleaning opening **336** but smaller compared with the second exhaust opening **324**. In this case, the Venturi effect can be made sure to be taken advantage of between the working cycles of the prime mover **20**, since the exhaust input opening **312** has a sectional area that is larger compared with the second cleaning opening **336**. In addition, since the sectional area of the exhaust input opening **312** is also smaller than that of the second exhaust opening **324**, the sidewall of the exhaust tip **31** would not protrude from the sidewall of the second exhaust opening **324**. Thus, the size of the whole self-cleaning prime mover exhaust system **30** could be smaller to save the inside space of the prime mover system **10**, and the exhaust tip **31** could also be commonly used by the exhaust pipe **32** and the cleaning tube **33** as a discharging output.

As shown in FIG. **4**, in some embodiments of the present application, the exhaust tip **31** may include an exhaust output opening **313** configured to be exposed to an outside ambient. In this case, the exhaust will be discharged into the air. However, in some other embodiments of the present application, the exhaust output opening **313** may extend through another system configured to collect or make use of the exhaust, for example, some exhaust recycling system, so that the surrounding environment can be protected from pollution.

As shown in FIGS. **4** and **5**, in some embodiments of the present application, the first exhaust section **321** may include a curved section **3211**, and the sidewall opening **323** may be located at an inflection position **3212** of the curved section **3211**. In some embodiments, the first exhaust section **321** may include multiple curved sections **3211**, so that the exhaust pipe **32** is in an "S" shape. Since the debris would suffer resistance when flows in the curved section **3211** and so would be easier being accumulated at the inflection position **3212** of the curved section **3211**, disposing of the sidewall opening **323** at the inflection position **3212** could help the debris exiting from the exhaust pipe **32**. More specifically, in some embodiments, the inflection position **3212** would be at a bottom of the curved section **3211** along a direction of gravity. In this case, the debris would automatically fall from the sidewall opening **323** at the inflection position **3212** because of gravity, which further facilitates the exiting of the debris from the exhaust pipe **32**. More specifically, in some embodiments, the sidewall opening **323** may be a water drain hole configured to direct water out of the exhaust pipe **32** towards a water drain. In this case, wastewater created during the working cycle of the prime mover **20** would fall with the debris from the sidewall opening **323**, and would not flow back to the prime mover **20**, so the safety risks would be caused by wastewater are further reduced.

As shown in FIG. **4**, in some embodiments of the present application, the first cleaning section **333** or the second cleaning section **334** includes a half tube disposed of on a surface of the exhaust pipe **32** and extending along the exhaust pipe **32**. The coupling manner of the half tube and the exhaust pipe **32** may be, but is not limited to, welding, riveting, adhesive bonding, or screw joint. In this case, the surface of the exhaust pipe **32** can be used as a half sidewall of the first cleaning section **333** or the second cleaning section **334**, so that the size of the whole self-cleaning prime mover exhaust system **30** could be smaller, and the manufacturing cost of the cleaning tube **33** could be reduced. As shown in FIG. **5**, in some other embodiments of the present application, the first cleaning section **333** or the second cleaning section **334** may include multiple end-to-end sections **3331**. The angles between each two adjacent end-to-end sections **3331** can be easily adjusted, so that the cleaning tube **33** can be more easily manufactured to couple with and extend along the surface of the exhaust pipe **32**. Thus, the size of the whole self-cleaning prime mover exhaust system **30** could be smaller, and the manufacturing difficulties of the cleaning tube **33** could be reduced.

In some other embodiments, the exhaust tip **31**, the exhaust pipe **32**, and the cleaning tube **33** may be manufactured or connected in some other manners. The manufacturing and connecting manners of the exhaust tip **31**, the exhaust pipe **32**, and the cleaning tube **33** are not limited to the examples discussed above.

FIG. **6** shows a flow chart illustrating a method of self-cleaning debris from a self-cleaning prime mover exhaust system, according to at least one embodiment described and recited herein. The self-cleaning prime mover exhaust system may be a prime exhaust system provided by any embodiment mentioned above.

As shown in FIG. **6**, at **501**, the exhaust is directed away from the prime mover through the exhaust pipe **32** during a working cycle of the prime mover.

At **502**, the debris exiting the sidewall opening **323** is accumulated into the cleaning tube **33**.

At **503**, the debris is vacuumed through the cleaning tube **33** and out of the self-cleaning prime mover exhaust system through the exhaust tip **31** using the Venturi effect.

It will be appreciated that the orders of **501** to **503** may vary. For example, in an embodiment, **501** may be implemented repeatedly, and **502** and **503** may be implemented between any two times of the implementations of **501**.

FIG. **7** illustrates a block diagram schematic of one embodiment of a power system **500** for powering a transport climate control system (e.g., the transport climate control systems **105**, **155**, **210**, **280** shown in FIGS. **1A-1D**). The power system **500** includes a prime mover power network **504**, and a transport climate control load network **512** connected to a power module **540**.

The prime mover power network **504** includes a prime mover **510** and an electric machine **505** that may provide electric power to the power module **540**. The prime mover **510** may be configured to generate mechanical power and the electric machine **510** may be configured to convert the mechanical power to electric power. The generated electric power is then sent by the prime mover power network **505** to the power module **540**. In some embodiments, the prime mover **510** may be a vehicle prime mover used to move the vehicle that also provides power to the transport climate control load network **512** when available. Mechanical power generated by the prime mover **510** that may be used in the system **500** may be inconsistent and based on operation and vehicle load requirements of the vehicle. In other embodiments, the prime mover **510** and the electric machine **505** may be part of a generator set that provides power to the transport climate control load network **512**. In yet further embodiments, the prime mover **510** and the electric machine **505** may be part of a CCU (e.g., the CCU **115**, **165**, **220**, **290** shown in FIGS. **1A-D**) to provide power to the transport climate control load network **512**. In some embodiments the maximum power available from the prime mover power network **504** may never be sufficient to operate the transport climate control system operating at a full capacity.

Components of the transport climate control load network **512** may be, for example, part of a CCU that is mounted to the body of the vehicle (for example, truck, van, etc.). In some embodiments, the CCU may be above the cab of the truck (as shown in FIG. **1B**). In one or more alternative embodiments, the CCU may be on the top of the TU (for example, a top of a box where the external condensers are located) (see FIG. **1C**). In one or more other embodiments, the components of the transport climate control load network **512** may be DC powered components. In one or more other embodiments, the components of the transport climate control load network **512** may be AC powered components.

Alternatively, the transport climate control load network **512** may include both DC powered components and AC powered components.

As shown in FIG. **7**, the transport climate control load network **512** includes at least one compressor **555**, one or more evaporator blowers **565**, one or more condenser fans **570**, the heater **575**, and the controller **560**. It will be appreciated that in some embodiments, the transport climate control load network **512** does not include the heater **575**. It will also be appreciated that in some embodiments, the transport climate control load network **512** does not include the at least one compressor **555**. It will further be appreciated that in some embodiments, the transport climate control load network **512** may include thermal management of batteries, power electronics, etc. The transport climate control load network **512** also includes an inverter **550** that may be configured to boost the load power and convert the boosted load power to an AC load power. That is, the inverter **550** may be configured to boost power from the DC load bus **52** and converts the power to AC power to drive the compressor **555**. In some embodiments, the inverter **550** may convert the load power to a high voltage AC power. As shown in FIG. **7**, the inverter **550** may be configured to power the compressor **555** and optionally the heater **575**. It will be appreciated that in other embodiments, the inverter **550** may power other components of the transport climate control load network **512** such as, for example, the one or more evaporator blowers **565**, the one or more condenser fans **570**, etc. In some embodiments, the inverter **550** may be a Compressor Drive Module (CDM).

The load DC bus **52** is connected to and powers each of the inverter **550**, the one or more evaporator blowers **565**, the one or more condenser fans **570**, the heater **575**, and the controller **560**. It will be appreciated that the inverter **550** with the compressor **555** may require the most power of the various loads of the transport climate control load network **512**. As shown in FIG. **7**, in some embodiments, the inverter **550** may also power the heater **575**.

Aspects:

It will be appreciated that any of aspects 1-22 can be combined.

Aspect 1. A self-cleaning prime mover exhaust system comprising:

an exhaust tip configured to eject exhaust out of the self-cleaning prime mover exhaust system;

an exhaust pipe configured to direct the exhaust away from a prime mover, wherein the exhaust pipe comprises:

a first exhaust section with a sidewall opening, and

a second exhaust section, comprising an exhaust opening configured to direct the exhaust out of the exhaust pipe; and

a cleaning tube having a first end and a second end, wherein the cleaning tube has a smaller sectional area compared with the exhaust tip, and the cleaning tube comprises:

a first cleaning section covering the sidewall opening, wherein the first cleaning section comprises a first cleaning opening at the first end of the cleaning tube, and

a second cleaning section extending through the exhaust tip, the second cleaning section comprising a second cleaning opening at the second end of the cleaning tube,

wherein the cleaning tube is configured to accumulate debris exiting the sidewall opening and configured to vacuum the debris out of the cleaning tube through the second cleaning opening and out of the self-cleaning prime mover exhaust system through the exhaust tip using the Venturi effect.

Aspect 2. The self-cleaning prime mover exhaust system of Aspect 1, wherein the second exhaust section extends through the exhaust tip and configured to direct the exhaust into the exhaust tip.

Aspect 3. The self-cleaning prime mover exhaust system of Aspect 2, wherein the exhaust tip has a larger sectional area compared with the exhaust pipe.

Aspect 4. The self-cleaning prime mover exhaust system of Aspect 2, wherein the exhaust tip comprises an exhaust end, and both the second exhaust section and the second cleaning section extend through the exhaust end.

Aspect 5. The self-cleaning prime mover exhaust system of Aspect 4, wherein both the exhaust opening and the second cleaning opening are disposed within the exhaust end.

Aspect 6. The self-cleaning prime mover exhaust system of Aspect 2, wherein the exhaust tip comprises an exhaust input opening, both the second exhaust section and the second cleaning section extend through the exhaust input opening, and

the exhaust input opening has a sectional area which is larger compared with the second cleaning opening but smaller compared with the second exhaust opening.

Aspect 7. The self-cleaning prime mover exhaust system of Aspect 1, wherein the exhaust tip comprises an exhaust output opening configured to be exposed to an outside ambient.

Aspect 8. The self-cleaning prime mover exhaust system of Aspect 1, wherein the first exhaust section comprises a curved section, and the sidewall hole is located at an inflection position of the curved section.

Aspect 9. The self-cleaning prime mover exhaust system of Aspect 8, wherein the inflection position is at a bottom of the curved section along a direction of gravity.

Aspect 10. The self-cleaning prime mover exhaust system of Aspect 9, wherein the sidewall opening is a water drain hole configured to direct water out of the exhaust pipe towards a water drain.

Aspect 11. The self-cleaning prime mover exhaust system of Aspect 1, wherein the first cleaning section or the second cleaning section comprises a half tube disposed of on a surface of the exhaust pipe and extending along the exhaust pipe.

Aspect 12. The self-cleaning prime mover exhaust system of Aspect 1, wherein the first cleaning section or the second cleaning section comprises multiple end-to-end sections.

Aspect 13. A prime mover system, comprising:

a prime mover configured to generate mechanical power; and

a self-cleaning prime mover exhaust system, comprising: an exhaust tip configured to eject debris out of a self-cleaning prime mover exhaust system; an exhaust pipe configured to direct exhaust away from a prime mover, wherein the exhaust pipe comprises: a first exhaust section with a sidewall opening, and a second exhaust section, comprising an exhaust opening configured to direct the exhaust; and a cleaning tube having a first end and a second end, wherein the cleaning tube has a smaller sectional area compared with the exhaust tip, and the cleaning tube comprises: a first cleaning section covering the sidewall opening, wherein the first cleaning section comprises a first cleaning opening at the first end of the cleaning tube, and a second cleaning section extending through the exhaust tip, the second cleaning section comprising a second cleaning opening at the second end of the cleaning tube, wherein the cleaning tube is configured to accumulate debris exiting the sidewall opening and configured to vacuum the debris out of the cleaning tube through the second cleaning opening and out of the self-cleaning prime mover exhaust system through the exhaust tip using the Venturi effect.

Aspect 14. The prime mover system of Aspect 13, wherein the second exhaust section extends through the exhaust tip and configured to direct the exhaust into the exhaust tip.

Aspect 15. The prime mover system of Aspect 14, wherein the exhaust tip comprises an exhaust end, and both the second exhaust section and the second cleaning section extend through the exhaust end.

Aspect 16. The prime mover system of Aspect 14, wherein the exhaust tip comprises an exhaust input opening, both the second exhaust section and the second cleaning section extend through the exhaust input opening, and

the exhaust input opening has a sectional area which is larger compared with the second cleaning opening but smaller compared with the second exhaust opening.

Aspect 17. The prime mover system of Aspect 13, wherein the exhaust tip comprises an exhaust output opening configured to be exposed to an outside ambient.

Aspect 18. The prime mover system of Aspect 13, wherein the first exhaust section comprises a curved section, and the sidewall hole is located at an inflection position of the curved section.

Aspect 19. The prime mover system of Aspect 13, wherein the first cleaning section or the second cleaning section comprises a half tube disposed of on a surface of the exhaust pipe and extending along the exhaust pipe.

Aspect 20. The prime mover of Aspect 13, further comprising an exhaust fan, configured to vacuum the exhaust from the exhaust pipe.

Aspect 21. The prime mover of Aspect 13, wherein the prime mover comprises a diesel motor.

Aspect 22. A method for self-cleaning debris from a self-cleaning prime mover exhaust system that includes: an exhaust tip configured to eject exhaust out of the self-cleaning prime mover exhaust system; an exhaust pipe configured to direct the exhaust away from a prime mover, wherein the exhaust pipe comprises: a first exhaust section with a sidewall opening, and a second exhaust section, comprising an exhaust opening configured to direct the exhaust; and a cleaning tube having a first end and a second end, wherein the cleaning tube has a smaller sectional area compared with the exhaust tip, and the cleaning tube comprises: a first cleaning section covering the sidewall opening, wherein the first cleaning section comprises a first cleaning opening at the first end of the cleaning tube, and a second cleaning section extending through the exhaust tip, the second cleaning section comprising a second cleaning opening at the second end of the cleaning tube, wherein the cleaning tube is configured to accumulate debris exiting the sidewall opening and configured to vacuum the debris out of the cleaning tube through the second cleaning opening and out of the self-cleaning prime mover exhaust system through the exhaust tip using the Venturi effect; and

the method comprises:

directing the exhaust away from the prime mover through the exhaust pipe during a working cycle of the prime mover;

accumulating the debris exiting the sidewall opening into the cleaning tube; and

vacuuming the debris through the cleaning tube and out of the self-cleaning prime mover exhaust system through the exhaust tip using the Venturi effect.

The terminology used in this Specification is intended to describe particular embodiments and is not intended to be limiting. The terms "a," "an," and "the" include the plural forms as well, unless clearly indicated otherwise. The terms "comprises" and/or "comprising," when used in this Specification, specify the presence of the stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, and/or components.

With regard to the preceding description, it is to be understood that changes may be made in detail, especially in matters of the construction materials employed and the shape, size, and arrangement of parts without departing from the scope of the present disclosure. This Specification and the embodiments described are exemplary only, with the true scope and spirit of the disclosure being indicated by the claims that follow.

I claim:

1. A self-cleaning prime mover exhaust system comprising:

an exhaust tip configured to eject exhaust out of the self-cleaning prime mover exhaust system;

an exhaust pipe configured to direct the exhaust away from a prime mover, wherein the exhaust pipe comprises:

a first exhaust section with a sidewall opening, and

a second exhaust section, comprising an exhaust opening configured to direct the exhaust out of the exhaust pipe; and

a cleaning tube extending along a surface of the exhaust pipe, the cleaning tube having a first end and a second end, wherein the cleaning tube has a smaller sectional area compared with the exhaust tip so as to create a vacuuming air flow in the cleaning tube because of the Venturi effect, and the cleaning tube comprises:

a first cleaning section covering the sidewall opening, wherein the first cleaning section comprises a first cleaning opening at the first end of the cleaning tube, and

a second cleaning section extending through the exhaust tip, the second cleaning section comprising a second cleaning opening at the second end of the cleaning tube,

wherein the exhaust pipe includes a bend at the sidewall opening that is configured such that debris in the exhaust pipe flows back away from the exhaust tip into the sidewall opening and into the cleaning tube between working cycles of the prime mover when there is no exhaust flow in the exhaust pipe, and

wherein the cleaning tube is configured to accumulate the debris exiting the sidewall opening between the working cycles of the prime mover when there is no exhaust flow in the exhaust pipe and configured to, between the working cycles of the prime mover, vacuum the debris out of the cleaning tube through the second cleaning opening and out of the self-cleaning prime mover exhaust system through the exhaust tip using the Venturi effect.

2. The self-cleaning prime mover exhaust system of claim **1**, wherein the second exhaust section extends through the exhaust tip and configured to direct the exhaust into the exhaust tip.

3. The self-cleaning prime mover exhaust system of claim **2**, wherein the exhaust tip has a larger sectional area compared with the exhaust pipe.

4. The self-cleaning prime mover exhaust system of claim **2**, wherein the exhaust tip comprises an exhaust end, and both the second exhaust section and the second cleaning section extend through the exhaust end.

5. The self-cleaning prime mover exhaust system of claim 4, wherein both the exhaust opening and the second cleaning opening are disposed within the exhaust end.

6. The self-cleaning prime mover exhaust system of claim 2, wherein the exhaust tip comprises an exhaust input opening, both the second exhaust section and the second cleaning section extend through the exhaust input opening, and

the exhaust input opening has a sectional area which is larger compared with the second cleaning opening but smaller compared with the second exhaust opening.

7. The self-cleaning prime mover exhaust system of claim 1, wherein the exhaust tip comprises an exhaust output opening configured to be exposed to an outside ambient.

8. The self-cleaning prime mover exhaust system of claim 1, wherein the first exhaust section comprises a curved section, and the sidewall hole is located at an inflection position of the curved section.

9. The self-cleaning prime mover exhaust system of claim 8, wherein the inflection position is at a bottom of the curved section along a direction of gravity.

10. The self-cleaning prime mover exhaust system of claim 9, wherein the sidewall opening is a water drain hole configured to direct water out of the exhaust pipe towards a water drain.

11. The self-cleaning prime mover exhaust system of claim 1, wherein the first cleaning section or the second cleaning section comprises a half tube disposed of on a surface of the exhaust pipe and extending along the exhaust pipe.

12. The self-cleaning prime mover exhaust system of claim 1, wherein the first cleaning section or the second cleaning section comprises multiple end-to-end sections.

13. A prime mover system, comprising:

a prime mover configured to generate mechanical power; and

a self-cleaning prime mover exhaust system, comprising: an exhaust tip configured to eject debris out of the self-cleaning prime mover exhaust system; an exhaust pipe configured to direct exhaust away from the prime mover, wherein the exhaust pipe comprises: a first exhaust section with a sidewall opening, and a second exhaust section, comprising an exhaust opening configured to direct the exhaust; and a cleaning tube extending along a surface of the exhaust pipe, the cleaning tube having a first end and a second end, wherein the cleaning tube has a smaller sectional area compared with the exhaust tip so as to create a vacuuming air flow in the cleaning tube because of the Venturi effect, and the cleaning tube comprises: a first cleaning section covering the sidewall opening, wherein the first cleaning section comprises a first cleaning opening at the first end of the cleaning tube, and a second cleaning section extending through the exhaust tip, the second cleaning section comprising a second cleaning opening at the second end of the cleaning tube, wherein the exhaust pipe includes a bend at the sidewall opening that is configured such that debris in the exhaust pipe flows back away from the exhaust tip into the sidewall opening and into the cleaning tube between working cycles of the prime mover when there is no exhaust flow in the exhaust pipe, and wherein the cleaning tube is configured to accumulate the debris exiting the sidewall opening between the working cycles of the prime mover when there is no exhaust flow in the exhaust pipe and configured to, between the working cycles of the prime mover, vacuum the debris out of the cleaning tube through the second cleaning opening and out of the self-cleaning prime mover exhaust system through the exhaust tip using the Venturi effect.

14. The prime mover system of claim 13, wherein the second exhaust section extends through the exhaust tip and configured to direct the exhaust into the exhaust tip.

15. The prime mover system of claim 14, wherein the exhaust tip comprises an exhaust end, and both the second exhaust section and the second cleaning section extend through the exhaust end.

16. The prime mover system of claim 14, wherein the exhaust tip comprises an exhaust input opening, both the second exhaust section and the second cleaning section extend through the exhaust input opening, and

the exhaust input opening has a sectional area which is larger compared with the second cleaning opening but smaller compared with the second exhaust opening.

17. The prime mover system of claim 13, wherein the exhaust tip comprises an exhaust output opening configured to be exposed to an outside ambient.

18. The prime mover system of claim 13, wherein the first exhaust section comprises a curved section, and the sidewall hole is located at an inflection position of the curved section.

19. The prime mover system of claim 13, wherein the first cleaning section or the second cleaning section comprises a half tube disposed of on a surface of the exhaust pipe and extending along the exhaust pipe.

20. A method for self-cleaning debris from a self-cleaning prime mover exhaust system that includes: an exhaust tip configured to eject exhaust out of the self-cleaning prime mover exhaust system; an exhaust pipe configured to direct the exhaust away from a prime mover, wherein the exhaust pipe comprises: a first exhaust section with a sidewall opening, and a second exhaust section, comprising an exhaust opening configured to direct the exhaust; and a cleaning tube extending along a surface of the exhaust pipe, the cleaning tube having a first end and a second end, wherein the cleaning tube has a smaller sectional area compared with the exhaust tip so as to create a vacuuming air flow in the cleaning tube because of the Venturi effect, and the cleaning tube comprises: a first cleaning section covering the sidewall opening, wherein the first cleaning section comprises a first cleaning opening at the first end of the cleaning tube, and a second cleaning section extending through the exhaust tip, the second cleaning section comprising a second cleaning opening at the second end of the cleaning tube, wherein the exhaust pipe includes a bend at the sidewall opening that is configured such that debris in the exhaust pipe flows back away from the exhaust tip into the sidewall opening and into the cleaning tube between working cycles of the prime mover when there is no exhaust flow in the exhaust pipe, and wherein the cleaning tube is configured to accumulate the debris exiting the sidewall opening between the working cycles of the prime mover when there is no exhaust flow in the exhaust pipe and configured to, between the working cycles of the prime mover, vacuum the debris out of the cleaning tube through the second cleaning opening and out of the self-cleaning prime mover exhaust system through the exhaust tip using the Venturi effect; and

the method comprises:

directing the exhaust away from the prime mover through the exhaust pipe during a working cycle of the prime mover;

during the working cycle of the prime mover, the debris in the exhaust pipe flowing with the exhaust and discharged from the exhaust tip;

between working cycles of the prime mover, the debris in the exhaust pipe flowing back away from the exhaust tip into the sidewall opening and accumulating in the cleaning tube;

and between the working cycles of the prime mover while no new exhaust is created and no exhaust flow in the self-cleaning prime mover exhaust system, the cleaning tube creating a Venturi effect and directing debris in the cleaning tube towards the exhaust tip and through the sidewall opening;

accumulating the debris exiting the sidewall opening into the cleaning tube; and

vacuuming the debris through the cleaning tube and out of the prime mover exhaust system through the exhaust tip using the Venturi effect.

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